

Newly Discovered Flows on the Sun's Surface

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An image-processing technique applied to solar Doppler velocity data from the Global Oscillations Network Group prototype instrument has enabled scientists to measure, with far better accuracy, the flow patterns on the surface of the Sun. These flows include a well-known east-west flow (differential rotation), a north-south meridional flow, and a cellular convective pattern in which the solar gases rise up from the interior, spread out across the surface, and sink inward around the edges of the cells. The meridional flow and the largest of the cellular flows have been particularly difficult to measure in the past. Both of these flows are now measured with enough accuracy to reveal unexpected details in their motions.

Solar astronomers have recognized that the Sun's magnetic field often exhibits a large cellular pattern with sunspots forming where the magnetic field becomes concentrated. The existence of a "giant-cell" convection pattern was suggested more than 30 years ago to explain these observations. However, all efforts to measure such flows have been unsuccessful or inconclusive. If such flows exist, it might be easier to predict the formation and evolution of sunspots and any associated activity such as flares or coronal mass ejections. The importance of predicting solar activity for planning space missions, for communications, and even for managing electrical

power distribution grids, makes the search for giant cells an important ongoing effort within the solar physics community.

At least two instruments for measuring flow patterns on the Sun have recently been developed. (1) The Global Oscillations Network Group project has established a ground-based network of telescopes. This project deployed its instruments at six sites around the world in 1995. It has operated a prototype instrument in Tucson, Arizona, since mid-1992. The instrument has good spatial resolution but is hampered by the Earth's atmosphere. (2) The Solar Oscillations Investigation-Michelson Doppler Imager team has developed a space-based telescope for the Solar and Heliospheric Observatory mission, which was launched by an Atlas 2AS in December of 1995. The spacecraft will orbit a point in space a million miles from the Earth in the Sun's direction where the Earth's and the Sun's gravitational pull are equal. Both of these instruments work on the same principal, but the Solar Oscillations Investigation instrument will have much better spatial resolution and will not be influenced by the Earth's atmosphere.

Data from the Global Oscillations Network Group prototype instrument was analyzed using an image-processing technique developed by the author. This technique extracts each component of the flow and accounts for the complete velocity signal. The results of the analysis indicate the presence of a weak meridional flow that fluctuates from about 20 meters per second (40 miles per hour) to more than 50 meters per second (100 miles per hour) over the course of several

months. The results also indicate the presence of a large cellular pattern like that expected for the giant cells.

Prior to this work, a meridional flow was known to carry magnetic field elements from the equatorial regions toward the poles. The precise structure of this flow and any variations with time were difficult to measure because of its relative weakness (the differential rotation produces east-west flows of about 200 meters per second or 400 miles per hour, and the small cellular pattern called "supergranulation" has flow speeds of about 500 meters per second or 1,000 miles per hour). The analysis of the Global Oscillations Network Group prototype data reveals both spatial structure and variations in time, as shown in figure 18. In late 1992, the meridional flow was poleward and less than about 30 meters per second. It increased to more than 50 meters per second in 1993 and then dropped to 20 meters per second in 1994 and 1995. Computer models for the transport of magnetic field elements across the solar surface had previously indicated that such changes might occur, and now these observations confirm that the Sun's meridional flow does change over fairly short time intervals.

The giant-cell convection pattern is also difficult to measure because of its relative weakness. The pattern is extracted by determining the full spectrum of the cellular convective motions and then extracting only the largest of these components. The resulting flow pattern for June 24, 1995, has all of the characteristics expected of giant-cell convection. Analysis of additional data in the days preceding and following

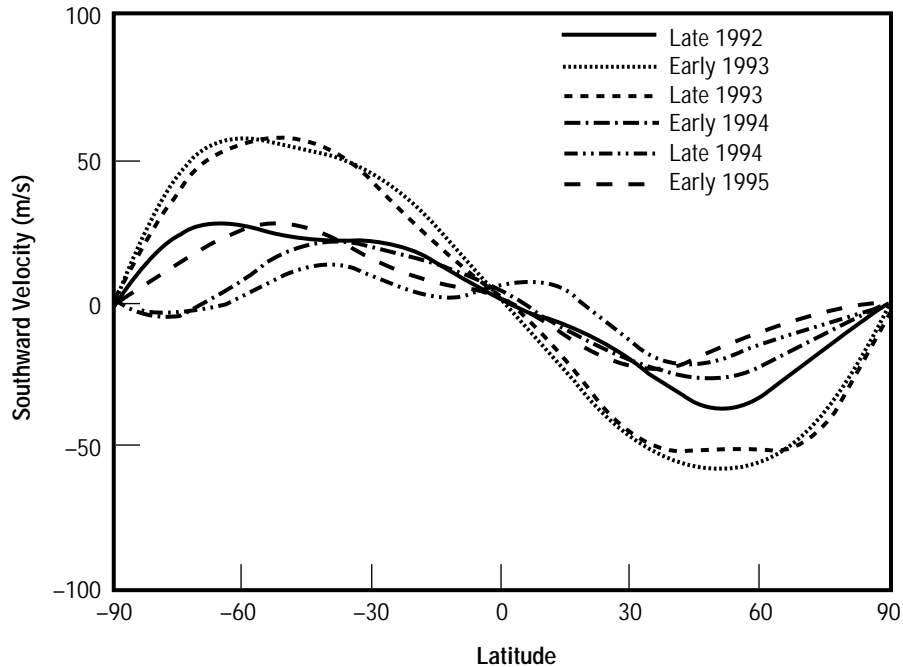


FIGURE 18.—The Sun's meridional flow velocity at 6-month intervals.

this shows that the flow pattern persists from day to day and rotates at about the same rate as the magnetic field pattern. These flows are also fairly weak, less than about 20 meters per second or 40 miles per hour, but they persist for days and probably even weeks or longer. The long lifetimes of these flows are important in organizing the large-scale magnetic field patterns.

Future work with data from both the Global Oscillations Network Group and Solar Oscillations Investigation instruments should produce additional information about these flows and about how they influence the Sun's magnetic field. These flows may also contain important information about the dynamics of the Sun's convection zone and the source of the 11-year sunspot cycle. With greater understanding of these flows,

researchers may someday be able to predict the emergence of sunspots and the occurrence of solar activity that influences the near-Earth environment.

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